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Non-Invasive Computed Tomography and Three-Dimensional Reconstruction of the Dentition of a 2,800-Year-Old Egyptian Mummy Exhibiting Extensive Dental Disease

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KEY WORDS attrition; caries; periodontal disease; exposed pulp, secondarily infected cyst; death

ABSTRACT A second CT scan of the mummy Djedmaatesankh, which is housed in the Royal Ontario Museum, Toronto, Ontario, has been undertaken after an interval of some 15 years. The image data set of her dentition and the associated tissues acquired from 3 mm thick × 3 mm spacing slices was transferred to an ISG Allegro work station where two-dimensional reformats and three-dimensional reconstructions were produced. This non-invasive examination provided information on dental disease that is, in a number of respects, an advance on that which previously could be obtained from mummies by the traditional methods of visual inspection after unwrapping and by two-dimensional radiography. The two- and three-dimensional images reveal that: three molars are missing and the right maxillary canine is impacted; the rest of the dentition is afflicted by severe attrition, caries and periodontal disease; and, of the 28 teeth present in the mouth, 24 exhibit exposure of their dental pulps and 18 are afflicted by periapical lesions including five that could have contributed to a large secondarily infected radicular cyst. The cyst has displaced the maxillary antrum and enlarged the maxilla on its lateral aspect and the vault of the palate on its medial aspect. Pus from the cyst may have drained through five different sinuses. In life, Djedmaatesankh's widespread dental infection probably caused her considerable pain, personal distress and malaise, and possibly resulted in her death. Am J Phys Anthropol 103:329–340, 1997.

X-ray computed tomography (CT) and three-dimensional reconstruction provides a valuable tool for examining mummies and fossils, and offers distinct advantages over the older methods of unwrapping mummies followed by autopsy, and of two-dimensional radiography (Lewin and Harwood-Nash, 1977; Lewin, 1978; Harwood-Nash, 1979; Vahey and Brown, 1984; Conroy and Vannier, 1987; Lewin, 1991; Baldock et al., 1994). Although the state of the dentition can provide useful information regarding ancient peoples (Ruffer, 1920; Krogman, 1948; Puech et al., 1980; Skinner et al.,

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1982; Bennike, 1985), few observations have been made on their teeth using CT. Vahey and Brown (1984) have commented on the absence of a maxillary and a mandibular incisor in a mummy as part of a general description of their CT findings. A specific CT study of a mummy's dentition was undertaken by Baldock et al. (1994) so that they could use its stage of development to establish the mummy's age, and Conroy and Vannier (1987) have used CT to determine the state of development of the unerupted permanent dentition in the Taung fossil skull.

Djedmaatesankh, a Theban woman from the 22nd Dynasty (~9th Century BC), is known from the inscription on her cartonnage to have been a lady musician in the Temple of Amun-Re at Karnak and to have been married to a doorkeeper in the same Temple (Dr. Nicholas Millet, personal communication). Preliminary observations using CT showed that her skeleton was free of any evidence of abnormality or degenerative disease and that she was a mature, nulliparous female.

Harwood-Nash (1979) published the results of the first CT study of Djedmaatesankh's intact mummy. He described the beautiful cartonnage in which the mummy is encased and reported on the structure of the mummy at various levels, but did not report on the condition of her teeth. In this communication, we report on the state of the dentition of Djedmaatesankh as revealed in a second non-destructive CT scan of the mummy. This scan was carried out some 15 years after the first using more advanced techniques than those employed initially. The approach has revealed a dentition ravaged by extensive attrition and disease, and the presence of widespread dental infection that we consider to have been a possible cause of her death.

MATERIALS AND METHODS

The mummy of Djedmaatesankh, which is housed in the Royal Ontario Museum, Toronto, Ontario, was transported to the Department of Imaging, Hospital for Sick Children, Toronto, Ontario for CT imaging. Handling of the cartonnage was reduced to a minimum by supporting it on a specially constructed board throughout the time that it was out of the museum. This board did not influence the quality of the diagnostic images.

The CT scan

A General Electric 9800 Quick scanner with Hi Light Detectors (GE Medical Systems-Americas, Milwaukee, WI) was used to produce both image slices and three-dimensional images using the following parameters: 1) 3 mm thick × 3 mm spacing through the head and neck using 120 kVp and 170 mAs for 2 sec. Detailed analysis of the dentition was not an objective at the time of image acquisition, so image slices 1 mm thick × 1 mm spacing that may have yielded more information regarding the oral and maxillofacial tissues were not employed (see Discussion); 2) 5 mm thick × 5 mm spacing through the thorax and abdomen, again using 120 kVp, 170 mAs for 2 sec; 3) 1.5 mm thick × 1.0 mm through the petrous bones and orbits; 10 mm thick × 10 mm spacing through the feet. The last two scans were performed using 120 kVp and 120 mAs for 2 sec.

All of the image data was archived onto nine-track tapes. The original scan data were also archived to allow for the possibility of high resolution retrospective images.

All of the image data were acquired in the axial mode. These data were transferred to an ISG Allegro work station (ISG Technologies, Mississauga, Ontario, Canada) where they were manipulated to produce two-dimensional reformats and three-dimensional image reconstructions of the head and neck. The two-dimensional reformats allowed the production of image slices in orientations different from the originally acquired axial mode.

Two types of two-dimensional images were produced. First, a panoramic type image layer: a curved slice that matched the contours of the maxillary and mandibular dental arches. This image is similar to that produced on the panoramic film used in modern dental clinics for the diagnosis of dental disease. Each of these image layers provided an image through the long axes of the teeth from an anterior-posterior direction. Using this technique, several image

layers were constructed through the width of the alveolar process and the contained teeth. Second, the image analysis software allowed for the reconstruction of images in any plane. This was done when diagnostic information additional to that provided by the originally acquired axial images and the panoramic reformats was required. This capability of image manipulation is important since the position of the body of the mummy could not be altered within the gantry of the CT in order to produce acquired images in other than the axial plane.

Three-dimensional reconstructed images of the bandaged face, facial skeleton, jaws and dentition were also produced by manipulating the pixels and the density algorithm. These images could be rotated and viewed from any perspective. Both soft and hard tissue anatomy could be highlighted by manipulating the density algorithm.

The attenuation of the resins and bandages was sometimes equal to adjacent structures such as the skin and soft tissue. Difficulty could also be encountered in the differentiation between the image densities of the soft tissues and the mineralized bone, unlike in the living patient. This could have resulted, at least in part, from the process of mummification.

Examination of the images

To permit comprehensive examination, magnified images of the dentition were produced following the initial examination of the original image data. The acquired axial images, the two-dimensional panoramic reformats and the three-dimensional reconstructions of each quadrant of the dentition and the surrounding osseous structures were first examined. Then, each tooth and its supporting structures were examined in greater detail. This examination often involved additional manipulation of the images. This included the isolation of components of the three-dimensional reconstructions or the removal of the superficial layers of the latter to expose components in situ ("electronic dissection"). Isolation of individual teeth facilitated examination of their interproximal surfaces or wear of their crowns, and occasionally was used to provide particular information about their root(s) and about periapical lesions. "Electronic dissection" was sometimes used to provide additional information about periapical lesions.

Classification of attrition

Attrition of Djedmaatesankh's teeth was examined primarily in three-dimensional reconstructions and exposure of the dental pulp chamber in the two-dimensional panoramic reformats. The CT images did not provide all of the detail that can be obtained from visual examination. Consequently, although a number of approaches have been used to record the extent and pattern of attrition in human teeth (Broca, 1879; Morrees, 1957; Murphy, 1959; Molnar, 1971; Smith, 1984), a modified classification has been devised to describe attrition seen in CT images. The most advanced stage of wear in each tooth is recorded: 0. No evidence of wear of the masticatory surface; 1. Wear of the masticatory surface, but the cusps are still evident on the posterior teeth; 2. Wear of the masticatory surface that has resulted in a tablelike surface; 3. Wear of the masticatory surface that has resulted in a scalloped surface; 4. Wear of the masticatory surface that has resulted in a scalloped surface in a tooth where the pulp chamber is exposed; 5. Wear of the masticatory surface that has resulted in a tablelike surface in a tooth where the pulp chamber is exposed; ( ). Wear of the masticatory surface where the pattern of wear could have been complicated by a carious lesion.

OBSERVATIONS

All of the teeth are present in the mouth except the right maxillary third molar and the left mandibular second and third molars, which are missing (Figs. 1 and 2), and the right maxillary canine, which is impacted (Fig. 3). Practically all of the teeth show considerable attrition of their masticatory surfaces (Figs. 1, 2 and 4, and Table 1), and this has resulted in exposure of dentine which frequently has been worn in concave fashion (Figs. 1 and 2). There is evidence of caries (Figs. 5 and 6). The pulp chambers of many of the teeth are exposed (Figs. 3 and 5). A large secondarily infected radicular cyst is located in the left maxilla (Figs. 3, 7 and 8) and there are numerous other periapi-

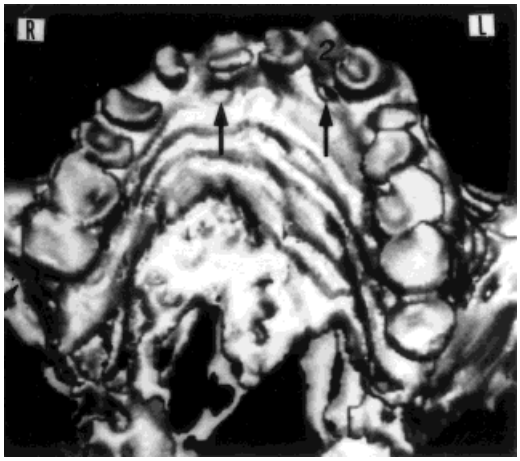

Fig. 1. Postero-inferior view of a three-dimensional reconstruction of the maxilla and contained teeth. Note the absence of the right third molar and of the alveolar ridge where the molar would have been located; the attrition of the masticatory surfaces; the labioversion of the left maxillary lateral incisor; the rugae and incisal papilla, the sinus in the palatal mucosa adjacent to the left lateral incisor and canine and the perforation adjacent to the right central incisor (long arrows); and the asymmetry of the palatal vault. L, left; R, right; 2, left maxillary lateral incisor.

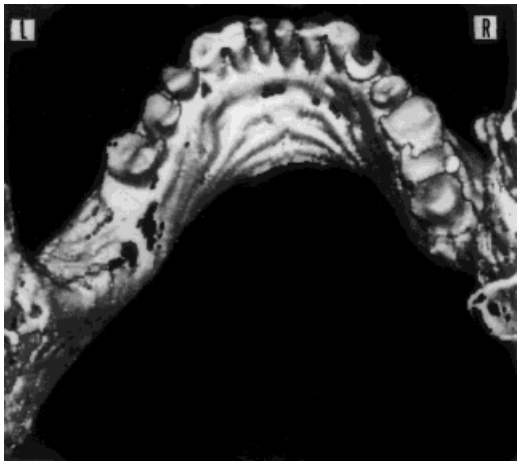

Fig. 2. Postero-superior view of a three-dimensional reconstruction of part of the mandible and the contained teeth. Note the attrition, the absence of the left second and third molars, and the atrophied alveolar ridge where the molars would have been located.

cal lesions (Figs. 3 and 8). The individual teeth exhibiting evidence of attrition, interstitial caries that may have impinged upon the worn masticatory surfaces, pulp exposure and periapical lesions are shown in Table 1. Destruction of alveolar bone consequent upon periodontal disease is also evident (Fig. 4).

The secondarily infected radicular cyst

The secondarily infected radicular cyst (Fig. 7) has been measured by the computer to be 31.9 mm mesio-distal, 19 mm bucco-palatal and 22.6 mm superior-inferior in its greatest dimensions, and to have a volume measured at 6 cm^3. It has encroached on and displaced the maxillary antrum superiorly (Fig. 3), and has expanded the maxilla laterally (Fig. 8) and the palate medially (see below). The apices of the roots of five teeth, the lateral incisor, canine, first and second premolars and the first molar, are closely associated with the lesion (see below) and their pulp chambers are exposed. Consequently, it is possible that they all contributed infection to the cyst.

The lateral incisor is the most mesial of the teeth that appear to have contributed to the lesion. It is labioverted (Fig. 1) and consequently shows less incisal wear than the adjacent teeth (Fig. 4), but there is attrition of its lingual surface, and the pulp chamber is exposed (Fig. 3). The root canal is of large diameter (Fig. 3) and there is destruction of bone around the root. Axial images show the lesion to reach mid-root, and three-dimensional images depict a coronal extention of the cyst along the mesio-labial, mesial and palatal aspects of the root (Fig. 7).

The cyst surrounds the apex of the root of the canine (Figs. 3 and 7). Although the first premolar is broken down and the apex of the root has been resorbed (Figs. 3 and 4), the cyst involves the end of the remaining root fragment, as well as the apex of the second premolar and the roots of the first molar (Figs. 3 and 7). While neither the second nor third molars appear to have contributed to the lesion, the cyst lies close to the palatal aspects of the roots of these teeth (Fig. 7).

There appear to be a number of pathways through which pus from the infected cyst could have drained: 1) through the extension of the cyst mesio-labial to the lateral incisor (Figs. 4, 7 and 8); 2) through a sinus palatal to the lateral incisor (Fig. 1); 3) through

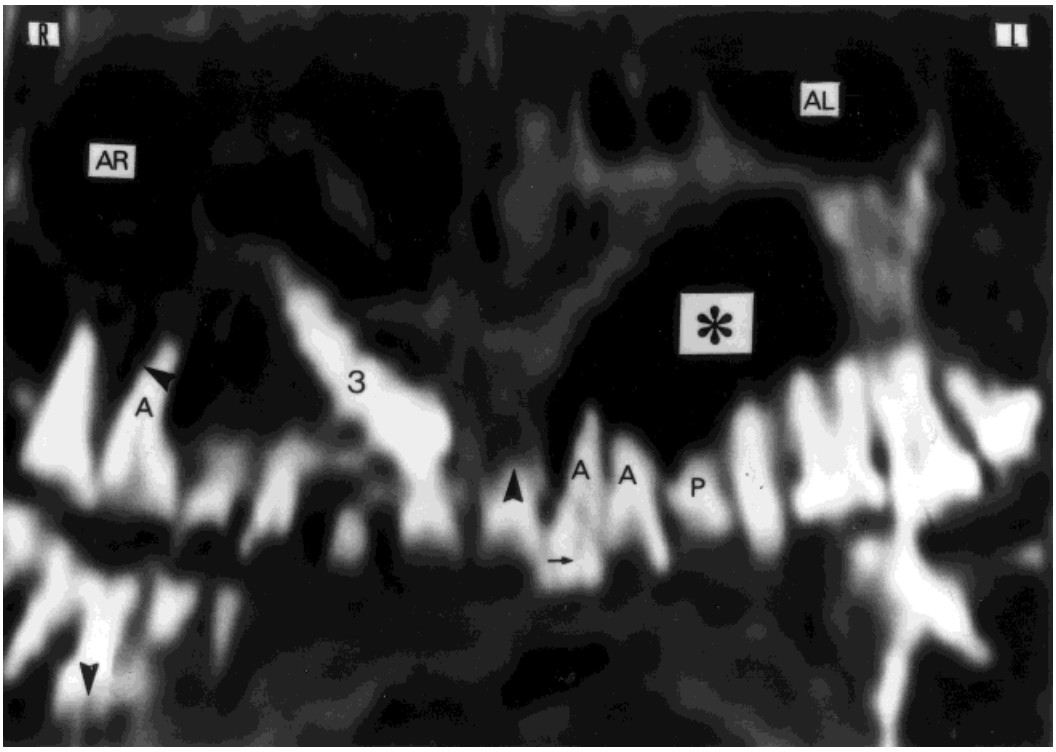

Fig. 3. Two-dimensional panoramic reformat of the dentition showing primarily the maxillary teeth. Note the impacted right canine; the secondarily infected cyst in the left maxilla (*), the related teeth and the displaced left maxillary antrum; teeth exhibiting exposed pulp chambers; periapical lesions (arrowheads); the large root canal in the left maxillary lateral incisor (arrow); and the broken-down left maxillary first premolar. A, teeth exhibiting exposed pulp chambers; AL, left maxillary antrum; AR, right maxillary antrum; P, left maxillary first premolar; 3, impacted right maxillary canine.

a sinus in the alveolar process that is located disto-superior to the apex of the canine (Fig. 8). Three-dimensional reconstruction of the alveolar process, the teeth and secondarily infected radicular cyst, and "electronic dissection" from the external surface of the bone, revealed the sinus to be slitlike in transverse section. The lumen of the sinus was measured by the computer to be 6.4 mm × 1.8 mm, with the greater dimension orientated approximately parallel to the long axis of the canine. An image corresponding to the external aspect of the bony sinus (Fig. 8) suggests that the sinus could have drained into the tissues of the face. We have sought evidence for a tract in three-dimensional reconstructions of the soft tissues but have not been able to confirm the possibility despite there being evidence for swelling of the face (Fig. 9); 4) through a sinus apical to the fragment of the first premolar. The gingival margin and alveolar bone on the labial aspect of the premolar had been resorbed (Fig. 4); 5) through a sinus into the nasal cavity (not shown).

The impacted right maxillary canine

The right maxillary canine is impacted in the palate and is orientated disto-superior to mesio-inferior. The palatal aspect of the crown of the canine has penetrated both the palatal mucous membrane adjacent to the central incisor (Fig. 1) and the socket of the incisor, leaving the palatal gingival margin intact. The labial aspect of the crown is in contact with the palatal aspect of the root of the central incisor and the former has caused erosion of the latter (not shown). Isolation of the right maxillary central and lateral incisors, the first premolar and their

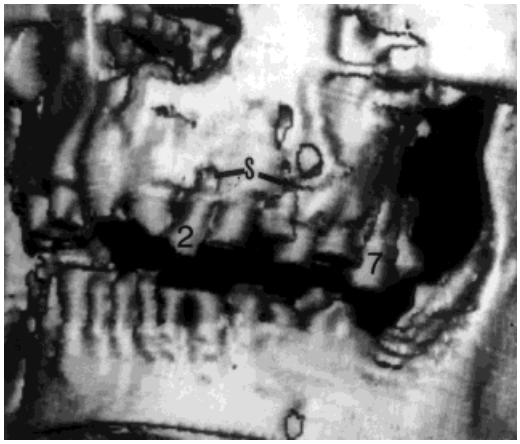

Fig. 4. Three-dimensional reconstruction of the jaws viewed from the left. Note the marked attrition affecting most of the teeth, but not the incisal edge of the left maxillary lateral incisor; the effect of periodontal disease on the height of the alveolar process, particularly in relation to the mandiblar anterior teeth; the breakdown of the left maxillary first premolar; the sinuses associated with the lateral incisor and the first premolar; and, the hyperuption of the second and third maxillary molars. S, sinus; 2, left maxillary lateral incisor; 7, left maxillary second molar.

associated periapical lesions from three-dimensional reconstructions revealed that the periapical lesions extend over the impacted canine (not shown).

The palate

An image consistent with rugae and an incisal papilla indicates the presence of palatal mucosa and gingiva (Fig. 1). Expansion of the left maxilla by the cyst has deformed the palatal vault (Figs. 1 and 8). There are two perforations in the mucosa, one caused by a sinus from the cyst and the other by the impacted canine (see above).

The missing molars

The left second and third mandibular molars are missing (Fig. 2). The opposing left second and third maxillary molars are hypererupted (Figs. 4 and 5); the crown of the former exhibits signs of attrition, as does that of the latter, but to a lesser degree (Fig. 1). The right third maxillary molar is missing (Fig. 1). The crowns of the opposing right second and third mandibular molars also exhibit signs of attrition (Fig. 2). There is no evidence of healing sockets or retained root fragments (Fig. 5), or of well-formed alveolar ridges (Figs. 1 and 2) in the bony sites that would have been occupied by the three missing molars.

DISCUSSION

Examination of the dentition using CT

We believe this to be the first report of a comprehensive examination of a mummy's dentition using CT and three-dimensional reconstruction. While two-dimensional radiography provides far more information on the dentition than does examination of an unwrapped mummy (Leek, 1979), the method used here is much more informative still. The power of CT for this type of examination is formidable and, in some respects, it provides more information than can be obtained from a routine clinical and radiological dental examination. It can provide the investigator with both two- and three-dimensional images of the soft and mineralized tissues in complex structures that can be viewed from any angle. It permits components of the three-dimensional structures to be isolated so that they also can be viewed from all aspects. "Electronic dissection" allows components to be viewed in situ. The removal of components can also be used to facilitate elucidation of spatial relationships. It provides for simultaneous viewing of correlated two- and three-dimensional images so that observations can be confirmed and anatomically elucidated. And, finally, it offers the means to measure the structures that it reveals.

The technology has allowed us to identify a number of pathological changes in the dentition of Djedmaatesankh. These include the lesions affecting each individual tooth, including the pattern of attrition affecting a given tooth, and the lesions affecting the related bone and soft tissues; the probable site of origin and the extent of the secondarily infected radicular cyst and some of its dimensions, the effect of the cyst on the anatomy of the maxilla and overlying soft tissue, and the sinuses through which contained pus may have drained; the orientation of the impacted maxillary canine, its relationship to, and effect on, the root of the adjacent central incisor and palatal mucosa, and the relationship between it and periapi-

TABLE 1. Lesions affecting individual teeth

Maxilla			Mandible		
Tooth	Attrition[1]	Periapical lesion	Tooth	Atrition[1]	Periapical lesion
Left					
Incisor 1	(4)	+	Incisor 1	3	
Incisor 2	4	+	Incisor 2	5	
Canine	(4)	+	Canine	4	
Premolar 1	(4)	+	Premolar 1	4	+
Premolar 2	4	+	Premolar 2	4	+
Molar 1	4	+	Molar 1	4	+
Molar 2	3		Molar 2[3]		
Molar 3	1		Molar 3[3]		
Right					
Incisor 1	(4)	+	Incisor 1	3	
Incisor 2	(5)	+	Incisor 2	4	
Canine[2]			Canine	4	
Premolar 1	(4)	+	Premolar 1	(4)	
Premolar 2	(4)	+	Premolar 2	4	+
Molar 1	4	+	Molar 1	4	+
Molar 2	4		Molar 2	(4)	+
Molar 3[3]			Molar 3	(4)	+

[1] Six levels of attrition are recorded. See Materials and Methods. Parentheses indicate that pattern of wear could have been complicated by a carious lesion.
[2] Impacted tooth.
[3] Missing teeth.

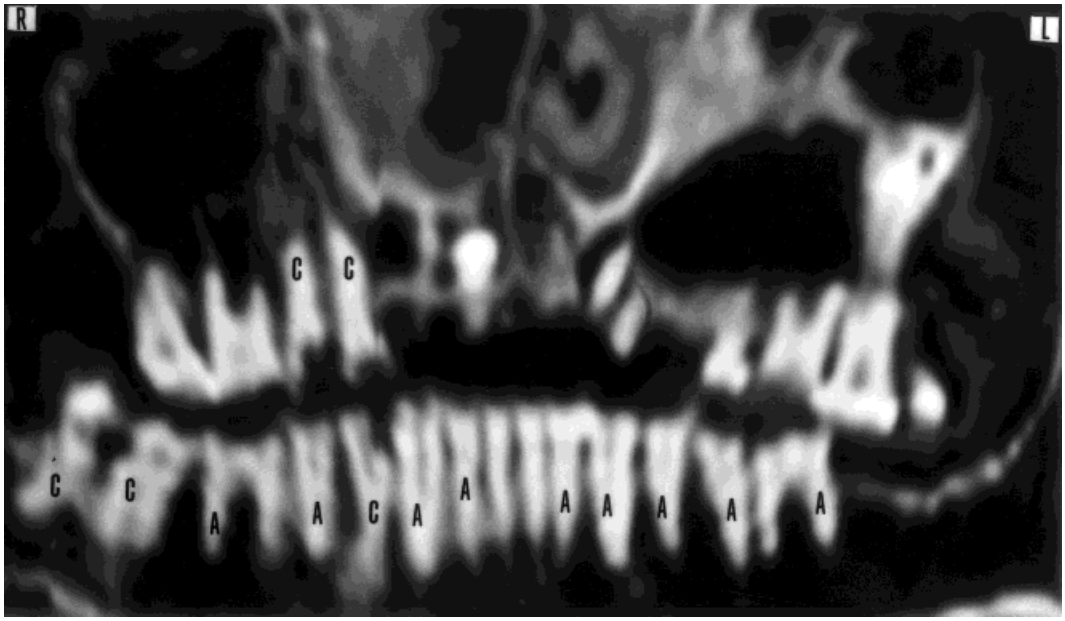

Fig. 5. Two-dimensional panoramic reformat primarily showing the mandibular teeth. Note the teeth that exhibit loss of interproximal tooth substance indicative of caries and those that exhibit exposure of their pulp chambers. The left maxillary second molar is hypererupted. A, teeth exhibiting exposed pulp chambers; C, teeth exhibiting interproximal caries.

cal lesions affecting adjacent teeth; and, the likelihood of missing teeth having been congenitally absent.

However, the technology used here does have limitations. It has not been possible to obtain all of the information that a CT scan undertaken in conjunction with a clinical examination in vivo could provide. For example, it is unlikely that small carious lesions that may have been present on the

Fig. 6. Three-dimensional reconstruction of right half of the mandible and its contained teeth. Note the carious cavities involving the mesial aspect of the first bicuspid and the buccal aspect of the third molar (arrowheads) and the occlusal attrition of the second and third molars.

surfaces of the teeth, such as those that are revealed clinically using a sharp dental probe, were resolved in the CT images. Furthermore, neither occlusal carious lesions that may have been established prior to the elimination of the occlusal fissures by attrition nor carious lesions that had been initiated on interproximal surfaces, but that had extended to involve the masticatory surface, could be identified with confidence on worn masticatory surfaces. Small exposures of the dental pulp, such as those that also can be identified with a sharp dental probe, and small facets on the occlusal surfaces of teeth, such as those that can be identified visually in clinical examination and that could provide evidence of the early effects of attrition, may not have been resolved. Except for sites where parapets of enamel were left surrounding areas from where dentine had been worn away by attrition, it was not possible to differentiate enamel from dentine, particularly when endeavouring to visualize the effects of attrition in three-dimensional reconstructions. Some of these shortcomings are inherent in the technology; for example, the inability to differentiate enamel from dentine in a three-dimensional image of a worn masticatory surface. Others arose out of the lack of fine detail in some images consequent upon the volume averaging that resulted from employing 3 mm scan widths. Use of 1 mm scan widths (Baldock et al., 1994) would have improved resolution and could be expected to have provided more detailed information about the dental tissues and their supporting structures.

Notwithstanding the limitations described above, it is evident that a wealth of information about the dentition can be obtained from CT as used here. Consequently, we suggest that CT scans of mummies should always include imaging of the jaws employing the narrowest scan widths possible and that, because of its advantages, CT should be used in preference to all of the other methods presently available for examining mummies.

Destruction of Djedmaatesankh's dentition

Djedmaatesankh suffered from extensive dental disease. Of the 28 teeth present in the mouth, the pulp chambers of 24 are exposed, 13 exhibit periapical lesions, and five could have been involved with the secondarily infected radicular cyst. She also suffered from extensive periodontal disease as revealed by the appreciable loss of bone supporting her teeth. It is probable that attrition and caries, as well as the infection that resulted from their destruction of the teeth and possibly from periodontal disease, caused her immense pain, suffering, personal distress and malaise. It is also possible that spread of the infection beyond the confines of her jaws was the cause of her death.

Dental attrition appears to have been a major cause of Djedmaatesankh's problems. In this condition, the masticatory surfaces of the teeth are worn down as coarse, fibrous or abrasive food is chewed between them. The hard, insensitive enamel is worn away initially, eventually exposing the underlying softer and sensitive dentine which is abraded more quickly, the surface often becoming scalloped as a result. If the destruction of the dentine progresses at a rate that is faster than is reactive dentinogenesis by pulp odontoblasts, the roof of the pulp chamber may be penetrated. This exposes the

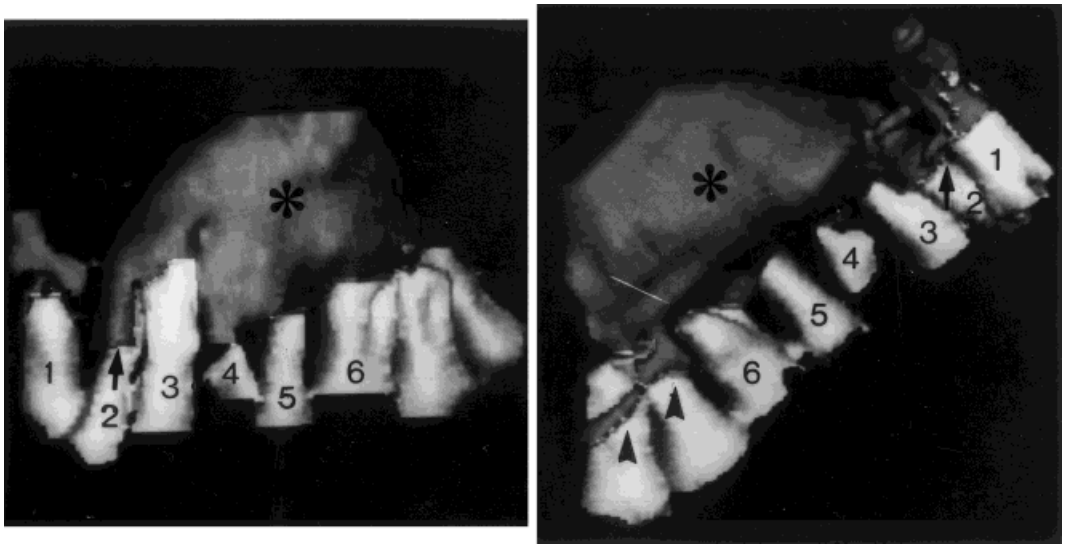

Fig. 7. Three-dimensional reconstruction showing the relationship between the left maxillary teeth and the associated secondarily infected cyst (*), viewed from the buccal (**left**) and from the palatal (**right**). Note the apparent involvement with the cyst of the lateral incisor, canine, both premolars and first molar; the extension of the cyst along the mesio-labial, mesial and palatal aspects of the root of the lateral incisor (arrows); the extension of the cyst beside the palatal aspect of the second and third molars (arrowheads). Although the periapical lesion associated with the central incisor may appear to be continuous with the cyst, analysis of the computer images shows them to be separate. 1 through 6, left maxillary central incisor through first molar respectively.

underlying pulp and, ultimately, by extension, the alveolar bone at the apex of the tooth, to bacterial infection from the oral cavity (Ruffer, 1920; Smith and Dawson, 1924; Leek, 1979). This could result in the formation of a periapical lesion, an apical granuloma, dental abscess or radicular cyst.

Dental attrition was widespread among the ancient Egyptians (Ruffer, 1920; Smith and Dawson, 1924; Leek, 1979; Harris et al., 1980) and was the predominant destructive lesion of tooth substance (Leek, 1979; Harris et al., 1980). While many of the foods eaten by the Egyptians could have contributed to the condition, the milling of the flour used to make bread may have played a particularly significant role. The flour was coarsely milled (Smith and Dawson, 1924) and was contaminated by fine debris from the millstones used to grind it as well as by fine sand particles (Ruffer, 1920; Brothwell and Brothwell, 1969; Leek, 1979). As bread formed an important part of the Egyptian diet, these three components, when chewed frequently, would effectively have worn away the enamel and dentine of the teeth (Ruffer, 1920).

Djedmaatesankh, like other ancient Egyptians, also suffered from caries (Ruffer, 1920; Bucaille, 1990), periodontal disease (Ruffer, 1920; Harris et al., 1980) and apical dental lesions (Ruffer, 1920; Harris et al., 1980). We diagnosed dental caries in our CT images with confidence only when there was substantial destruction of the interproximal, facial or oral surfaces of a tooth. However, it was frequently evident that destruction of tooth substance by an interproximal lesion could have extended to the occlusal surface. Our observations on Djedmaatesankh's carious teeth are consistent with those made directly on the teeth of the much more ancient Kabwe fossil (Puech et al., 1980); his caries also appears to have developed interdentally.

The secondarily infected radicular cyst

Diagnosis of the large radiolucent area in the left maxilla as a commonly occurring secondarily infected radicular cyst was based on the curved shape of the lesion, and on the fact that it occupied a space by displacing

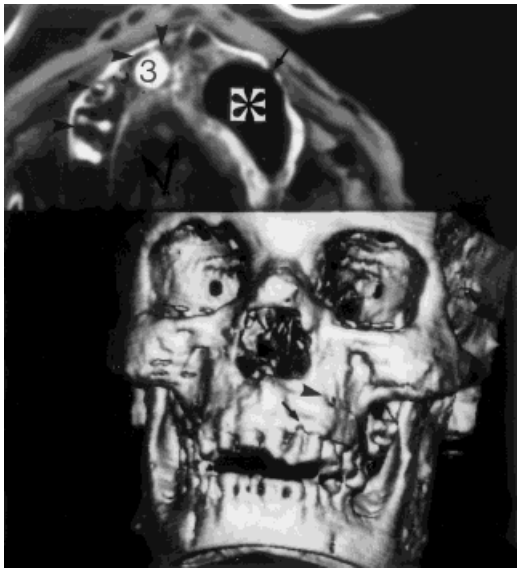

Fig. 8. An originally acquired axial image viewed from below (**top**) and a frontal view of a three-dimensional reconstruction of the facial skeleton (**bottom**). The expansion of the left maxillary alveolar process and the orifice of the sinus at its surface (arrowhead, bottom) correlates with the cyst (*, top) and its sinus (small arrow, top). Note the notch indicating a sinus in the alveolar margin of the maxillary left lateral incisor (small arrow, bottom) in the three-dimensional reconstruction. Radiolucent areas (arrowheads, top) that indicate periapical lesions are associated with apices of the right maxillary teeth and the palate is deformed (branched arrow, top). 3, impacted right maxillary canine.

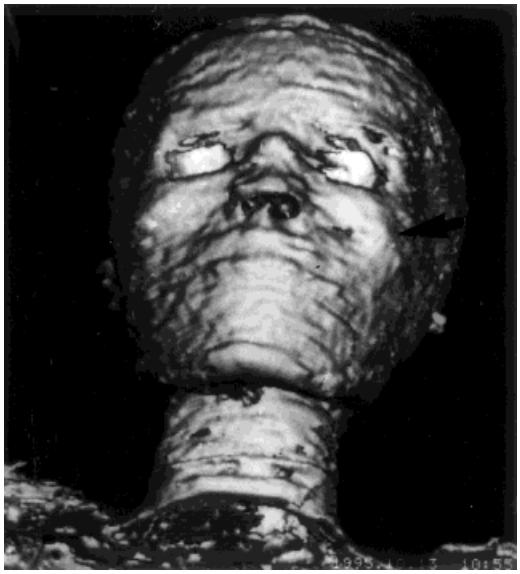

Fig. 9. Three-dimensional reconstruction of the face seen from the front and below. Note the swelling of the left cheek (arrow).

the floor of the antrum, the lateral aspect of the maxilla and the palate.

The contour of the area of rarefaction related to the apex of the lateral incisor suggests that this tooth could have been the epicentre of the lesion. This belief is supported by the following. First, the tooth, which was labioverted and hypererupted, exhibits considerable attrition on its lingual aspect. The mineralized tissue covering the pulp is thinner here than that found incisally, so it could have been abraded relatively quickly. Mastication on the thin dentine that was exposed following attrition of the enamel could have led to repetitive noxious stimuli being transmitted to the pulp, development of an acute pulpitis and necrosis of the pulp relatively early in its life. A clue to the early death of the pulp is provided by the comparatively large diameter of the root canal, an indication of early necrosis of the odontoblasts. Second, the lateral incisor would have erupted at least 5 years earlier than any of the other teeth which may have contributed to the lesion, with the exception of the first molar. While both of these teeth would have been subjected to attrition from the time that they reached occlusion, it is evident that, because of its anatomy, the destruction of the incisor would have occurred the more quickly of the two. It is also worth noting that, in modern populations, the most common teeth involved with radicular cysts are believed to be maxillary incisors (Shear, 1983).

There may be another explanation for the early necrosis of the pulp, and that is trauma. A sharp blow to the tooth could have disrupted the blood supply to the dental pulp, and this would have been followed by its death.

The infected pulps of the canine, the two premolars and the first molar may have contributed bacteria to the enlarging cyst.

Loss of teeth

There is no evidence to suggest that dental extraction was used as a therapeutic

procedure to treat toothache in ancient Egypt (Ruffer, 1920; Breasted, 1930; Ghalioungui, 1983; Weeks, 1980). It is consequently difficult to explain the absence of Djedmaatesankh's three molars. The two third molars could have been congenitally absent (Regezi and Sciubba, 1993). However, three-dimensional reconstruction of the crowns of the teeth that would have opposed them exhibit signs of attrition. Consequently, it is reasonable to conclude that both third molars had erupted into function prior to being lost. Attrition of the opposing teeth confirms that the left mandibular second molar had also erupted into occlusion.

A common cause of tooth loss among ancient Egyptians was periodontal disease (Harris et al., 1980). Djedmaatesankh's dentition shows clear evidence of generalised periodontal disease. This could explain the considerable resorption of the alveolus related to the absent second and third molars that was seen in the three-dimensional reconstructions. It is therefore possible that the teeth were lost as a result of periodontal disease. Another possibility is that the teeth were destroyed by caries but, unless they were extracted, one could expect the CT scan to have revealed fragments of their roots lying in the bone from where the teeth were lost. The only conclusion relating to the absence of the three teeth that can be drawn with confidence is that they were lost some time before death: there is no radiological evidence of healing sockets in the sites where the teeth were once located.

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LITERATURE CITED

Baldock C, Hughes SW, Whittaker DK, Taylor J, Davis R, Spencer AJ, Tonge K, and Sofat A (1994) 3-D Reconstruction of an ancient Egyptian mummy using X-ray computer tomography. J. R. Soc. Med. *87:*806–808.

Bennike P (1985) Palaeopathology of Danish Skeletons. A Comparative Study of Demography, Disease and Injury. Copenhagen: Adademisk Forlag.

Breasted JH (1930) The Edwin Smith Surgical Papyrus, vol 1. Chicago: University of Chicago Press.

Broca P (1879) Instructions relatives a l'etude anthropologique du système dentaire. Bull. Soc. Anthropol. (Paris) *2:*128–165.

Brothwell D and Brothwell P (1969) Food in Antiquity. A Survey of the Diet of Early Peoples. London: Thames and Hudson.

Bucaille M (1990) Mummies of the Pharaohs. Translated by Alastair D. Pannell and Maurice Bucaille. New York: St. Martin's Press.

Conroy GC and Vannier MW (1987) Dental development of the Taung skull from computerized tomography. Nature *329:*625–627.

Ghalioungui P (1983) The Physicians of Pharaonic Egypt. Cairo: Al Ahram Center for Scientific Translations.

Harris JE, Storey AT, and Ponitz PV (1980) Dental disease in the royal mummies. In JE Harris and EF Wente (eds.): An X-ray Atlas of the Royal Mummies. Chicago: University of Chicago Press, pp. 328–345.

Harwood-Nash DCF (1979) Computed tomography of ancient Egyptian mummies. J. Comput. Assist. Tomogr. *3:*768–773.

Krogman WM (1948) The skeletal and dental pathology of an early Iranian site. Bull. Hist. Med. *8:*28–48.

Krogman WM and Baer MJ (1980) Age at death of pharaohs of the New Kingdon, determined from x-ray films. In JE Harris and EF Wente (eds.): An X-ray Atlas of the Royal Mummies. Chicago: University of Chicago Press, pp. 188–285.

Leek FF (1979) The dental history of the Manchester mummies. In RA David (ed.): Manchester Museum Mummy Project. Multidisciplinary Research on Ancient Egyptian Mummifiefd Remains. Manchester: Manchester Museum, pp. 65–77.

Lewin PK (1978) Whole body scan of an Egyptian mummy using x-ray computed axial tomography. Paleopathol. Newslett. *22:*T7–8.

Lewin PK (1991) Technological innovations and discoveries in the investigation of ancient preserved man. In DJ Ortner and AC Aufderheide (eds.): Human Paleopathology: Current Syntheses and Future Options. Washington, D.C.: Smithsonian Institution Press, pp. 90–91.

Lewin PK and Harwood-Nash DCF (1977) X-ray computed axial tomography of an Egyptian brain. IRCS Med. Sci. *5:*78.

Molnar S (1971) Human tooth wear, tooth function and cultural variability. Am. J. Phys. Anthropol. *34:*175–190.

Moorrees CFA (1957) The Aleut Dentition. Cambridge, Mass.: Harvard University Press.

Murphy T (1959) The changing pattern of dentine exposure in human tooth attrition. Am. J. Phys. Anthropol. *17:*167–178.

Puech P-F, Albertini H, and Mills NTW (1980) Dental destruction in Broken-Hill Man. J. Hum. Evol. *9:*33–39.

Regezi JA and Sciubba J (1993) Oral Pathology, 2nd ed. Philadelphia: W.B. Saunders.
Ruffer A (1920) Study of abnormalities and pathology of ancient Egyptian teeth. Am. J. Phys. Anthropol. *3:*335–382.
Shear M (1983) Cysts of the Oral Regions. London: Wright PSG.
Skinner MF, Sperber GH, and Tobias PV (1982) Atlas of Radiographs of Early Man New York: Alan R. Liss.
Smith BH (1984) Patterns of molar wear in hunter-gatherers and agriculturalists. Am. J. Phys. Anthropol. *63:*39–56.
Smith GE and Dawson WR (1924) Egyptian Mummies. London: George Allen and Unwin.
Vahey T and Brown D (1984) Comely Wenuhotep: Computed tomography of an Egyptian mummy. J. Comput. Assist. Tomogr. *8:*992–997.
Weeks KR (1980) Ancient Egyptian dentistry. In JE Harris and EF Wente (eds.): An X-ray Atlas of the Royal Mummies. Chicago: University of Chicago Press.